Chapter(2)

Orbital Mechanics

One of the four fundamental forces in nature is gravity. Gravity is the force responsible for the motion of galaxies, stars and planets in the universe.

Launching an artificial satellite and keeping it in a stable orbit around Earth depends on a delicate balance between all forces acting on the satellite. The main forces to be balanced are the gravitational pull of the Earth and the centrifugal pushing force due to rotation.

A classical Newtonian approch to the subject of satellite orbits is sufficient for all practical reasons and aspects needed to launch and track satellites. An approch that depends on general relativity is an overkill. This is in regards to orbital mechanics, however in regards to synchronization and signal processing, general and special relativity are usually invoked to get the required accuarcy in those aspects.

2.1. Kepler's Laws:

The orbits followed by artifitial satellites orbiting Earth are calculated according to the same mechanical laws governing the motion of planets around the sun. Those laws are Kepler's laws which were derived by observations and then used by Newton to derive his famous laws of motion.

Kepler's first law: [for satellites]

- The orbit of each satellite is an elipse with the center of the earth at one of its focii.

Kepler's second law:

- The line joining the satellite and the center of the Earth sweeps equal areas in equal times.

Kepler's third law:

- The square of the orbital period, T, is directly proportional to the cube of the semimajor axis, a.

$$T^2 \propto a^3$$

$$\Rightarrow \quad a^3 = \frac{\mu}{\left(\frac{2\pi}{T}\right)^2} = \frac{\mu}{n^2}$$

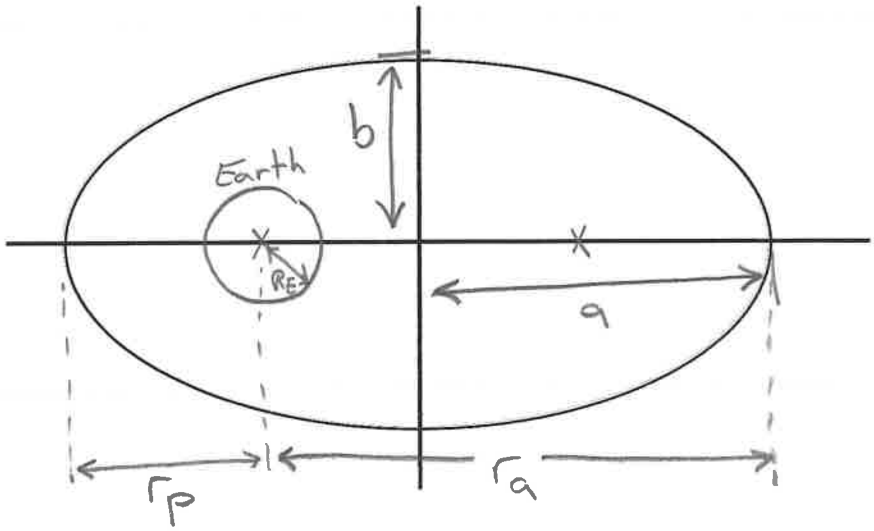
where μ is the prop. constant $= 3.986005 * 10^{14}$ $[m^3/s^2]$

and n is the angular speed in rad/sec

$$n = \frac{2\pi}{T}$$

2.2. Geometry of an elipse :

The ellipse is defined by its eccentricity, e



$$e = \frac{\sqrt{a^2 - b^2}}{a}$$, where

$a \equiv$ Semi-major axis

always $a \geq b$

$b \equiv$ semi-minor axis

$r_a \equiv$ apogee radius , $r_a = a(1+e)$

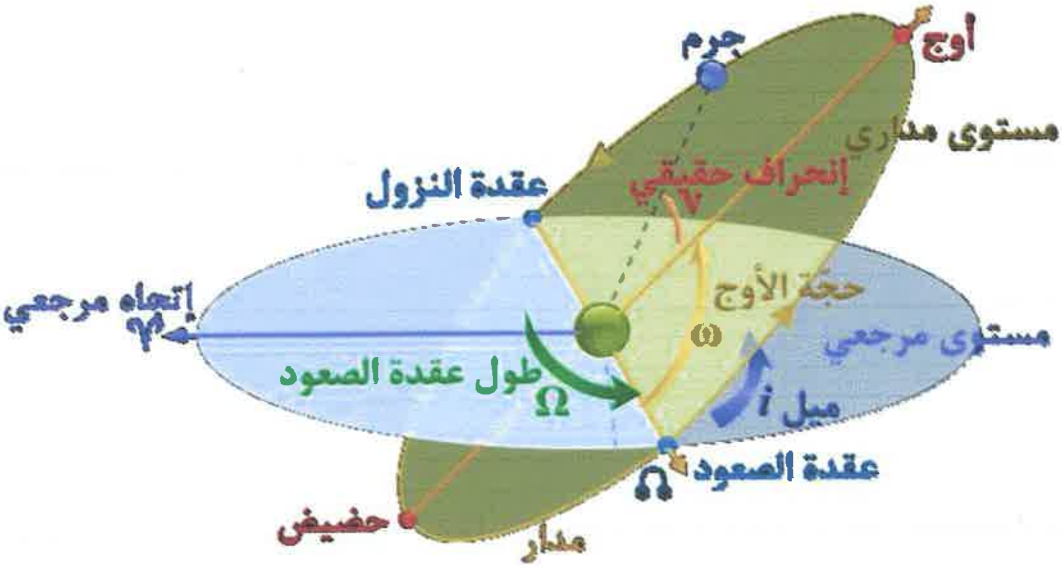
$r_p \equiv$ perigee radius , $r_p = a(1-e)$

$$0 < e < 1$$

if $a = b$	if $b = 0$
$\Rightarrow e = 0$; circle	$\Rightarrow e = 1$; line

2.3. Inclined orbits.

The important elements to define an inclined orbit are show in the figure below.



Orbit	مدار
Satellite	جرم
Orbital plane	مستوى مداري
Equiterial plane	مستوى مرجعي
Ascending node	عقدة الصعود
Descending node	عقدة النزول
Inclination θ°	ميل
First point of Aries [Spring Equinox]	اتجاه مرجعي ♈
Right Ascention of Ascending Node – RAAN Ω°	طول عقدة الصعود
Apogee / Perigee	أوج / حضيض
Argument of perigee (not apogee) ω°	حجة الأوج
True Anomaly	انحراف حقيقي